DEGRADATION OF ORGANIC MATTER USING MICROBUBBLE DIFFUSER

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CERTIFICATION OF APPROVAL

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Approved by,

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TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

WAN KARIMAH BINTI WAN ZID

ABSTRACT

Aeration in biological wastewater treatment is where air is introduced to the aeration tank for mixing purposes and to enhance biological growth. Air or oxygen is supplied to the activated sludge by aerators. Fine bubble diffusion is a subsurface form of aeration in which air is introduced in the form of fine bubbles built from porous materials. However, in an attempt to increase the efficiency of biological treatment of wastewater, the performance of fine and micro bubble diffusion aeration systems was investigated in this study. The study evaluated the effectiveness of the micro bubble diffuser compared to the millimeter bubble diffuser in the treatment of municipal wastewater. Two batch reactors of size 140x140x600 mm were fabricated. Porous sintered glass with porosities of 10-16 micron was used to produce the micro bubbles. Perforated aluminum disc of 3 mm thick with pore diameters ranging from 0.1-0.4 mm was fabricated to produce millimeter size air bubbles. Compressed air at a pressure of 63 kPa was forced through the diffusers from the bottom of the reactor at a flow rate of 2.5 L/min. Seed biomass for the wastewater treatment was obtained from a University Technology of Petronas sewage treatment plant (STP). The raw wastewater for the batch study was also taken from the STP. The wastewater sample was treated for a detention time of 48 hours and repeated for two runs. Sampling were conducted at 3 hours and 6 hours, for the first and second run, respectively. The effectiveness of both diffusers was evaluated based on removals of chemical oxygen demand (COD), and soluble chemical oxygen demand (SCOD). From the study it was found that the micro bubble diffuser has higher effectiveness in removing COD and SCOD with the average reaction coefficient k, of 0.041 and 0.0595, respectively. However, the average reaction coefficient k, for COD and SCOD using millimeter bubble diffuser was found to be 0.0275 and 0.044, respectively. The average removal of COD was found to be 86.8 % and 80.4 % for the micro bubble and millimeter bubble diffusers, respectively. The average removal of SCOD was found to be 90.9% and 75.1% for the micro bubble and millimeter bubble diffusers, respectively. It was also found that the micro bubble diffuser and millimeter bubble diffuser could saturate distilled water to 9.67 mg/L in 22 minutes and 94 minutes, respectively. As a conclusion, micro bubble diffuser was found to be efficient in the degradation of organic matter.

ACKNOWLEDGEMENT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water is consumed by every human every day in their daily lives either for drinking or cleaning purposes. With the growth of human population, the higher the demand for the fresh water supply. The greater amount of fresh water is being consumed will contribute to the increase in wastewater production. This will lead to the crucial need of treating the wastewater for the future fresh water supplement to the consumer.

In the wastewater treatment, aeration is the process which air is introduced to the wastewater to provide aerobic condition for the bacterial degradation of organic matter. The purposes of aeration are to supply the oxygen required for metabolizing microorganisms and to provide mixing to provide sufficient contact between the microorganisms and the dissolved and suspended organic matter. [1]

Aeration system consists of the subsurface and mechanical types. Subsurface system is where air is introduces to the wastewater by diffusers or devices submerge in the wastewater usually at the bottom of the aeration tank. A mechanical system agitates the wastewater using mechanical devices such as propellers, and blades or etc to introduce air from the atmosphere. [1]

The one that will be discussing is the aeration using fine pore diffusers, one type of the diffusers. Fine pore diffusers that will be used later on are of the millimeter and micrometer bubble size. Fine pore diffuser is a subsurface form of aeration in which the air is introduce to the wastewater in the form of very small bubbles. Fine pore diffusion of air brings great interest due to its high oxygen transfer efficiency. Smaller bubbles result in more bubble surface area per unit volume and greater oxygen transfer efficiency.

1.2 Problem Statement

In the wastewater treatment system, the standard aerators were used in the secondary treatment process to support the biological growth of the organisms in the aeration tank. However, this standard aerators required high horse power and produce turbulence air flow. So, the fine bubble diffusers are now commonly used in biological treatment plant. The implementation of these fine bubble diffusers is because of its durability; replace ability and economic reasons.

Fine bubble diffusers provide larger interfacial area for oxygen transfer as the air bubbles dimension is small enough [2]. This fulfills the goal of aeration which is to absorb air into the water. This absorption is influence by the interaction between the air and wastewater. Rate of organic matter degradation depends on the diffusion rate of oxygen into the water. By enhancing the oxygen diffusion rate, higher organic matter removal can be obtained.

Apart from that, it can produce laminar air flow without much turbulence occurrence. This will lead to the floatation or lifting up effect to the waste particles in the wastewater [2,3]. However, to produce the fine bubble with perforated disk of small hole is limited to the machining capability [2]. Hence, the porosity disk is used as another option of producing smaller bubbles which theoretically will gives higher oxygen transfer to the wastewater.

The diffuser which is using perforated disk will be call millimeter bubble diffuser while the diffuser with sintered porosity glass will be call micro bubble diffuser. Both of these diffusers is categorized as fine bubble diffusers and will be study in this research. The significance of this project is to come with a higher efficiency of diffused aeration system to be implemented in the real wastewater treatment field.

1.3 Objective and Scope of Study

The objective of this study is to evaluate the effectiveness of the micro bubble diffuser and millimeter bubble diffuser in removing Chemical Oxygen Demand (COD), and Soluble Chemical Oxygen Demand (SCOD). The scope of study comprises of removal of Chemical Oxygen Demand (COD), and Soluble Chemical Oxygen Demand (SCOD).

CHAPTER 2

LITERATURE REVIEW

Wastewater need to be treated in order for it to meet the standard before it was release to the stream or river. One of the main pollutants in the wastewater is organic matter. In this project, our main concern is to remove the organic matter in wastewater by using fine air bubble diffusers, micro bubble and millimeter bubble. To conduct the experiments, researches about diffused air system, dissolved oxygen, aeration process, aerobic biological oxidation process and types of wastewater used had to be done to the understand more about the project itself.

2.1 Diffused Air System

Diffusion is the movement of a substance from an area of higher concentration to an area of lower concentration. In this case of oxygen, if the air in the atmosphere has a higher concentration of oxygen than water - oxygen diffuses or is pushed from the air into the water. Usually, diffusers are placed at the bottom of the sludge water interface that is why they are called submerged air diffusers. To produce fine bubbles, perforated disk or porosity disk is used as a medium between the air and the water. The air was introduced into the water by flowing through the perforated disk or porosity disk. The air flow was controlled so that the bubbles produce is small and has laminar flow [5].

Submerged air diffusers are used in wastewater treatment facilities to increase dissolved oxygen (DO) levels and promote water circulation. Submerged diffusers release air or pure oxygen bubbles at depth, producing a free, turbulent bubble-plume that rises to the water surface through buoyant forces at roughly an 11° angle of spreading [4]. The ascending bubble plume entrains water, causing vertical circulation and lateral surface spreading. Oxygen transfers to the water across the bubble interfaces as the bubbles rise from the diffuser to the water surface.

When a submerged diffuser is operated, there are two main interfaces over which oxygen transfer occurs. Oxygen transfer occurs across the bubble interfaces as the bubbles rise through the water column. Oxygen transfer also occurs across the water surface at the air– water interface. The bubble-transfer rate involves some additional considerations. The liquid-phase equilibrium concentration of a given bubble is not only a function of temperature and atmospheric pressure, but also hydrostatic pressure and gas-phase oxygen composition. As bubbles rise, bubble–water gas transfer of oxygen, nitrogen, argon, carbon dioxide, and trace gases occurs due to a concentration gradient between the equilibrium bubble concentration and the ambient water concentration. Over depth, the bubble–water transfer of all gases affects the gas-phase oxygen composition and the equilibrium oxygen concentration. The equilibrium oxygen concentration inside a bubble also depends on gas flow rate and the changing bubble–water transfer coefficient over depth [2,3].

Diffused air system is the mechanisms on how the oxygen was transferred into the water. However, the importance of the dissolved oxygen and its significance will be elaborated below.

2.2 Dissolved Oxygen

Dissolved oxygen is a significant characteristic in wastewater treatment processes. The functioning of aerobic processes, such as activated sludge, biological filtration, and aerobic digestion, depends on the availability of sufficient quantities of oxygen. The most common application of oxygen transfer is in the biological treatment of wastewater. Because of the low solubility of oxygen and the consequent low rate of oxygen transfer, sufficient oxygen to meet the requirements of aerobic waste treatment does not enter water through normal surface air-water interfaces. To transfer the large quantities of oxygen that are needed, additional interfaces must be formed. Either air or oxygen can be introduced into the liquid, or the liquid in the form of droplets can be exposed to the atmosphere [5].

To estimate the apparent volumetric mass transfer coefficient, K_La value of oxygen transfer in clean water can be determined by a simplified mass transfer model equation below:

$$\frac{Cs - C_t}{Cs - Co} = e^{-(K_La)t} \quad \text{...(1)}$$

K_La = overall liquid film coefficient

C_t = concentration in liquid bulk phase at time t, mg/ L

C_s = concentration in equilibrium with gas as given by Henry's Law

C_o = initial concentration

In an activated-sludge system, the apparent volumetric mass transfer coefficient, *KLa* value can be determined by considering the uptake of oxygen by microorganisms. Typically, oxygen is maintained at a level of 1 to 3 mg/L and the microorganisms use the oxygen as rapidly as it is supplied. In equation form [5],

$$\frac{dC}{dt} = K_La\,(C_s - C) - r_M dt \quad \text{...(2)}$$

C = concentration of oxygen in solution

r_M = rate of oxygen used by the microorganisms

Typical values of r_M vary from 2 to 7 g/d per gram of mixed-liquor volatile suspended solids (MLVSS). If the oxygen level is maintained at a constant level, *dC/dt* is zero and

$$r_M = K_La\,(C_s - C) \quad \text{...(3)}$$

C in this case is constant also.

Values r_M can be determined in a laboratory by using a respirometer. In this case K_La can easily be determined as follows:

$$K_L a = \frac{r_m}{(C_s - C)} \quad \text{...(4)}$$

Prediction of oxygen transfer rates in aeration systems is nearly always based on an oxygen rate model. The overall oxygen mass transfer coefficient *KLa* is usually determined, in test or full-scale facilities. If pilot-scale facilities are used to determine *KLa* value' scale-up must be considered. The mass transfer coefficient *KLa* is also a function temperature, intensity of mixing (and hence of the type of aeration device used and the geometry of the mixing chamber), and constituents in the water [5].

There are several factors which can affect the dissolved oxygen in the wastewater or water such as temperature, altitude, mixing intensity or amount of air flow, tank geometry and wastewater characteristics. However, through out the project these factors are kept constant so that comparison can be made on the same base. Since we already know how to obtain the oxygen transfer rate, let us move on what happened to the dissolved oxygen when it is absorb into the wastewater. Mainly, oxygen will be consumed to oxidize the organic matter. Detail explanations are as below.

2.3 Aerobic Biological Oxidation Process

Aerobic wastewater treatment uses microorganism to feed on waste in the water and convert them to carbon dioxide and water. To keep the process going, the wastewater needs to be aerated with oxygen. The purpose of aeration of water is the improvement of their physical and chemical characteristics, the removal or reduction of taste and odor and precipitation of inorganic contaminants such as iron and manganese. In water treatment, the purpose of aeration is to ensure continued aerobic conditions for the microorganism to degrade the organic matters [1].

If sufficient oxygen is available, the aerobic biological decomposition of an organic waste will continue until all of the waste is consumed. Three more or less distinct activities occur. First, a portion of the waste is oxidized to end products to obtain energy for cell maintenance and the synthesis of new cell tissue.

Oxidation:

$$COHNS+O_2+bacteria \rightarrow CO_2 + H_2O + NH_3 + \text{other end products} + energy \ldots\ldots\ldots\ldots (5)$$

Simultaneously, some of the waste is converted into new cell tissue using part of the energy released during oxidation.

Synthesis:

$$COHNS+O_2+bacteria+energy \rightarrow \underset{\text{New cell tissue}}{C_5H_7NO_2} \ldots\ldots\ldots\ldots (6)$$

Finally, when the organic matter is used up, the new cells begin to consume their own cell tissue to obtain energy for cell maintenance. This third process is called endogenous respiration.

Endogenous respiration:

$$C_5H_7N0_2+5O_2+bacteria \rightarrow 5CO_2+2H_20+NH_3+energy \ldots\ldots\ldots\ldots (7)$$

Using the term COHNS (which represents the elements carbon, oxygen, hydrogen, nitrogen, and sulfur) to represent the organic waste and the term $C_5H_7NO_2$ [first proposed by Hoover and Porges (1952)] to represent cell tissue, the three processes are defined by the following generalized chemical reactions [5]:

General information on the biological oxidation process is not enough for us to determine the efficiency of a biological treatment system. So, further study on the organic matter degradation and microbial growth in the system need to be done. All of this will be explain next in the microbial growth kinetics.

2.4 Microbial Growth Kinetics

The performance of biological process used for wastewater treatment depends on the dynamics of substrate utilization and microbial growth. The kinetics of the microbial growth governs the oxidization of substrate and the production of biomass, which contributes to the total suspended solids concentration in biological reactors. Wastewater contains numerous substrates; the concentration of the organic matter is defined by *biodegradable* COD (bCOD) or UBOD, both of which are comprised of soluble (dissolved), colloidal, and particulate biodegradable components. The biomass solids in a bioreactor are commonly measured as *total suspended solid* (TSS) and *volatile suspended solid* (VSS) [5].

One of the principle concerns in wastewater treatment is the removal of substrate. The substrate utilization in biological system can be modeled with the following expression for soluble substrates. Because the mass of substrate is decreasing with the time due to substrate utilization and equation below is used in substrate mass balances, a negative value is shown [5],

$$r_{su} = \frac{-kXS}{K_s + S} \quad \text{.......(8)}$$

Where r_{su} = rate of substrate concentration change due to utilization, $g/m^3.d$

k = maximum specific substrate utilization rate, g substrate/g microorganism.d

X = biomass (microorganism) concentration, g/m^3

S = growth-limiting substrate concentration in solution, g/m^3

K_s = half-velocity constant, substrate concentration at one-half the maximum specific utilization rate, g/m^3

When the substrate is being used at its maximum rate, the bacteria are also growing at their maximum rate. The maximum specific growth rate of the bacteria is thus related to the maximum specific substrate utilization rate as follows [5].

$$\mu_m = kY \quad \text{and} \quad k = \mu_m / Y \qquad (9)$$

Where μ_m = maximum specific bacterial growth rate, g new cells/g cells.d

k = maximum specific substrate utilization rate, g/g.d

Y = true yield coefficient, g/g

Substituting k into the previous equation, we have the second equation

$$r_{su} = \frac{-\mu_m XS}{Y(K_s + S)} \qquad (10)$$

The biomass growth rate is proportional to the substrate utilization rate by synthesis yield coefficient, and biomass decay is proportional to the biomass present. The following relationship between the rate of growth and the rate of substrate utilization is applicable in both batch and continuous culture systems [5].

$$\begin{aligned} r_g &= - Y r_{su} - k_d X \\ &= Y \frac{kXS}{K_s + S} - k_d X \end{aligned} \qquad (11)$$

Where r_g = net biomass production rate, g VSS/m^3.d

Y = synthesis yield coefficient, g VSS/g bsCOD

k_d = endogenous decay coefficient, g VSS/gVSS.d

If the net biomass production equation is divided with the biomass concentration, X the specific growth rate is defined as follows:

$$\mu = \frac{r_g}{X} = Y \frac{kS}{K_s + S} - k_d \qquad (12)$$

Where μ = specific biomass growth rate, g VSS/g VSS.d

The specific growth rate corresponds to the change in biomass per day relative to the amount of biomass present, and is a function of the substrate concentration and the endogenous decay coefficient. Table 2.1 shows typical kinetics coefficients for the activated sludge process for the removal of organic matter from domestic wastewater.

Table 2.1: Typical Kinetics Coefficient for the Activated-Sludge Process for the Removal of Organic Matter from Domestic Wastewater

Coefficient	Unit	Value [a]	
		Range	Typical
k	G bsCOD/g VSS.d	2 – 10	5
K_s	mg /L BOD	25 – 100	60
	mg /L bsCOD	10 – 60	40
Y	mg VSS/mg bsCOD	0.4 – 0.8	0.6
	mg VSS/mg BOD	0.3 – 0.6	0.4
k_d	g VSS/gVSS.d	0.06 – 0.15	0.10

[a] Values reported are for 20˚C

Using all the equations above, we can determine the rate of substrate depletion and biomass growth rate. Since, the experiment conducted will be batch reactors the modeling treatment process kinetics will be explain in the next part batch reactor with reaction.

2.5 Batch Reactor with Reaction

Materials-balance equation for reactor for relative constituents is written as follows:

$$Accumulation = inflow - outflow + generation$$

Or can be represented in an equation form

$$dC/dt\ (V) = QC_0 - QC + r_cV$$

However, in the batch reactor, $Q = 0$, as there is no inflow and outflow in the reactor. The resulting equation for the batch reactor is

$$dC/dt = r_c = -k$$

Usually, there difference in the rate of change; accumulation terms and the rate of generation or utilization or decay term. In other condition except for batch reactor, these terms are not equal. Special case like batch reactor the terms is the same due to no inflow and outflow [5]..

$$Accumulation = Generation$$

When the flow is not occurring, the concentration per unit volume is changing according to the applicable rate expression. However, when there is flow in the reactor, the concentration in the reactor is changing by the inflow and outflow [5]..

If the rate of reaction is defined as first order, $r_c = -kC$, integrating between the limits $C = C_0$ and $C = C$ and $t = 0$ and $t = t$ yields the resulting expression

$$C/C_0 = e^{-kt} \text{ or } ln\ (C/C_0) = kt$$

Where

C = COD value at t time

C_0 = limiting COD value

However, these rates can be differing according to the wastewater types that we are using. Some of the wastewater may contain contaminants which can retard the microbial growth and only contain cert amount of organic matter. Wastewater characteristics part will elaborate more on this matt

2.6 Wastewater Characteristics

Wastewater is sewage, storm water, and water that have been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Most communities generate wastewater from both residential and nonresidential sources.

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater, but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants. The wastewater components that should be of most concern to homeowners and communities are those that have the potential to cause disease or detrimental environmental effects.

In this project, we are focusing on the residential wastewater. Residential wastewater is types of wastewater generated from every room in a house. Sewage varies regionally and from home to home based on such factors as the number and type of water-using fixtures and appliances, the number of occupants, their ages, and even their habits, such as the types of foods they eat. However, when compared to the variety of wastewater flows generated by different nonresidential sources, household wastewater shares many similar characteristics overall. There are two types of domestic sewage; one is blackwater, wastewater from toilets, and greywater, wastewater from all sources except toilets. Blackwater and greywater have different characteristics, but both contain pollutants and disease-causing agents that require treatment. Table 2.2 shows the constituents in the typical residential wastewater [5].

Table 2.2: Characteristics of Typical Residential Wastewater [a]

Parameter	Mass Loading	Concentration
Total Solids	115 - 170	680 - 1000
Volatile Solids	65 - 85	380 - 500
Suspended Solids	35 - 50	200 - 290
Volatile Suspended Solids	25 - 40	150 - 240
BOD_5	35 - 50	200 - 290
Chemical Oxygen Demand	115 - 125	680 - 730
Total Nitrogen	6 - 17	35 - 100
Ammonia	3 - 5	6 - 18
Nitrites and Nitrates	<1	<1
Total Phosphorus	3 - 5	8 - 29
Phosphate	1 - 4	6 - 24
Total Coliforms[b]	-	$10^{10} - 10^{12}$
Fecal Coliforms[b]	-	$10^{8} - 10^{10}$

[a] For typical residential dwellings equipped with standard water-using fixtures and appliances (excluding garbage disposals) generating approximately 45 gpcd (170 lpcd).

[b] Concentrations presented in organisms per liter.

CHAPTER 3

METHODOLOGY

Two batch reactors of size 140x140x600 mm were fabricated. Porous sintered glass with porosities of 10-16 micron was used to produce the micro bubbles. Perforated aluminum disc of 3 mm thick with pore diameters ranging from 0.1-0.4 mm was fabricated to produce millimeter size air bubbles. Compressed air at a pressure of 63 kPa was forced through the diffusers from the bottom of the reactor at a flow rate of 2.5 L/min. Figure 3.1 below shows the schematic diagram of experimental set-up and Figure 3.2 show the real experimentation equipment. Figure 3.3 and Figure 3.4 shows both type of the diffuser used.

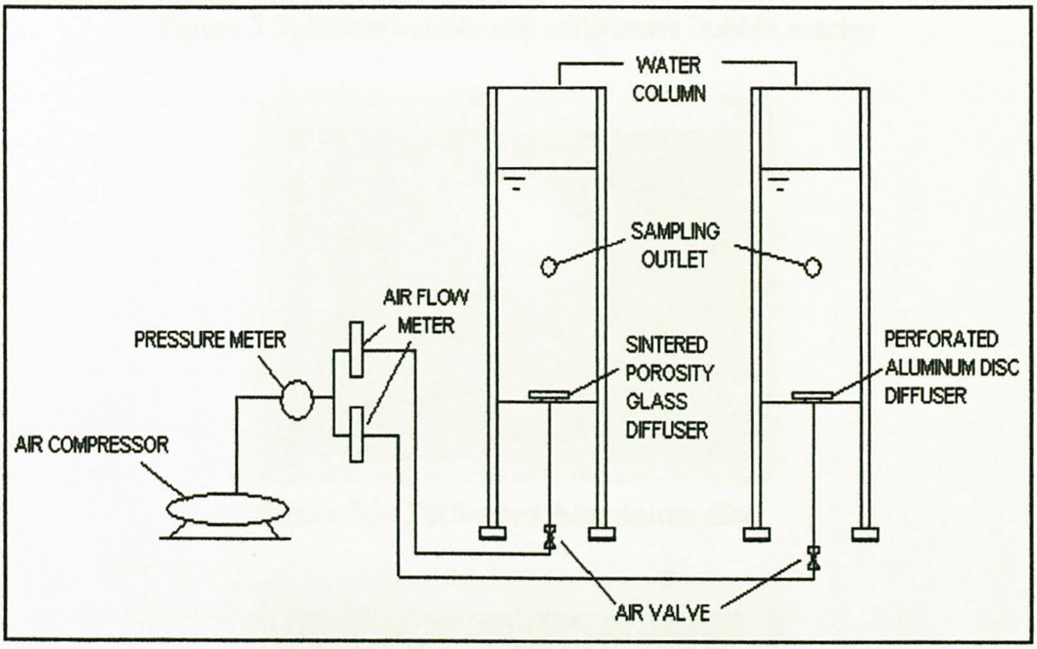


Figure 3.1: Schematic diagram of experimental set-up

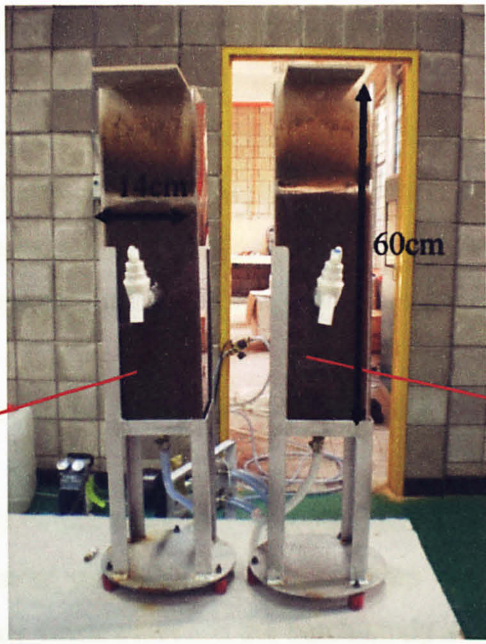


Figure 3.2: Micro bubble and Millimeter bubble reactor

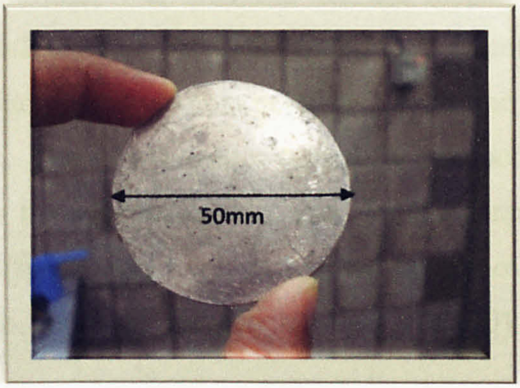


Figure 3.3: Perforated Aluminium disc

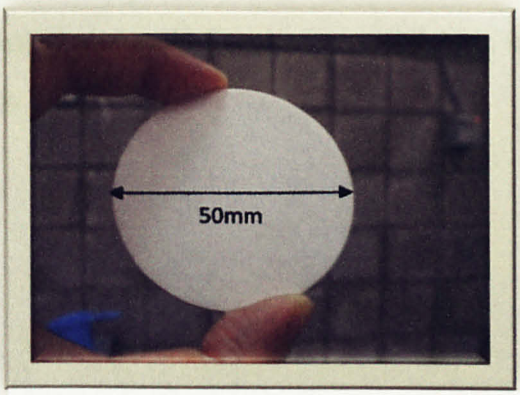


Figure 3.4: Sintered Porosity Glass

3.1 Experimental procedure for dissolved oxygen saturation

In this preliminary study, the effect of using the diffusers on water saturation was evaluated. In this experiment, six litres of distilled water was placed in both reactors. The increase of DO over a period of time was monitored for both reactors until saturation was achieved. The measurement of DO was monitored at 2 minutes interval.

3.2 Experimental procedure for removal of organics

Seed biomass for the wastewater treatment was obtained from a University Technology of Petronas sewage treatment plant (STP). The biomass was acclimatized for 2 weeks prior to the study. The raw wastewater for the batch study was also taken from the STP. One litre of the biomass was mixed with 5 litres of raw wastewater and placed into both reactors. The raw wastewater was analyzed for the initial COD and SCOD. The wastewater samples in both reactors was then aerated for a detention time of 48 hours and repeated for two runs. Sampling were conducted at 3 hours and 6 hours, for the first and second run, respectively. The samples were settled for two hours prior to measurement of the parameters. Only the supernatant was used for the parameter measurement. The effectiveness of both diffusers was evaluated based on removals of chemical oxygen demand (COD), soluble chemical oxygen demand (SCOD), ammonia-nitrogen and nitrate-nitrogen.

In the preliminary experiment, only TCOD was monitored throughout the study period of 6 hours. Air flow was introduced to both reactors, at 1 L/min and the sample was taken every one hour for testing.

3.3 Measurement of parameters

3.3.1 Chemical Oxygen Demand (COD)

2 ml of wastewater sample (supernatant) was measured and poured into a test tube containing potassium dichromate. This step was repeated three times to ensure accurate data is obtained. Test tube is then shaken properly. Heat was produces, indicating an exothermic process. This procedure is repeated by every sample. All the test tubes together with a blank as an indicator were put into the reactor with 150°C and left for 2 hours. After 2 hours, the test tube was removed from the reactor and was let cool for 15 minutes before the reading was measured using spectrophotometer.

3.3.2 Soluble Chemical Oxygen Demand (SCOD)

The supernatant was filtered using single cell-filtered equipment. 2 ml of wastewater sample (filtered supernatant) was measured and poured into a test tube containing potassium dichromate. This step was repeated three times to ensure accurate data is obtained. Test tube is then shaken properly. Heat was produces, indicating an exothermic process. This procedure is repeated by every sample. All the test tubes together with a blank as an indicator were put into the reactor with 150°C and left for 2 hours. After 2 hours, the test tube was removed from the reactor and was let cool for 15 minutes before the reading was measured using spectrophotometer.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Dissolved Oxygen Results

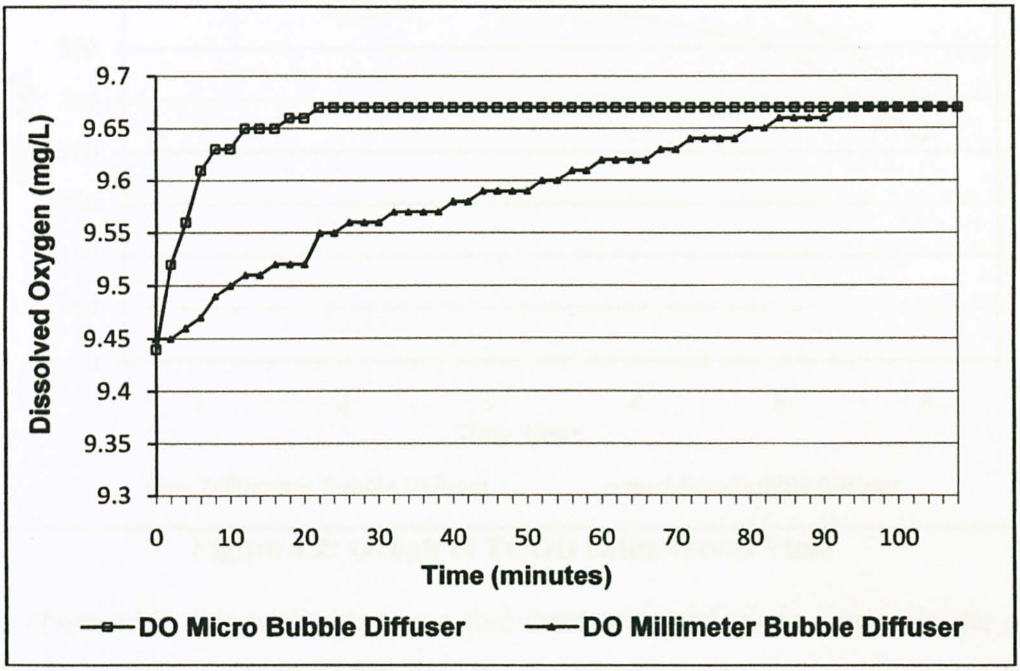


Figure 4.1: Graph of DO versus Time

Effect of water saturation using different diffusers was evaluated using distilled water. The dissolved oxygen (DO) concentration in the distilled water was measured at intervals of 2 minutes with an air flow of 0.5 L/min into the both reactors. From Figure 4.1, it can be observed that the DO concentration reached its saturated value of 9.67 mg/L in 22 minutes for the micro bubble diffuser while it took 94 minutes for the millimeter bubble diffuser to saturate the water at 9.67 mg/L. Theoretically, by enhancing the rate of oxygen diffusion into the system, it will promote significant inclination in bacterial growth and result in higher and faster removal of organic matter in the wastewater. Hence, it will prove the effectiveness of micro bubble diffuser in aeration or oxygen diffusion.

4.2 TCOD and SCOD Removal Results

4.2.1 Preliminary Experiment

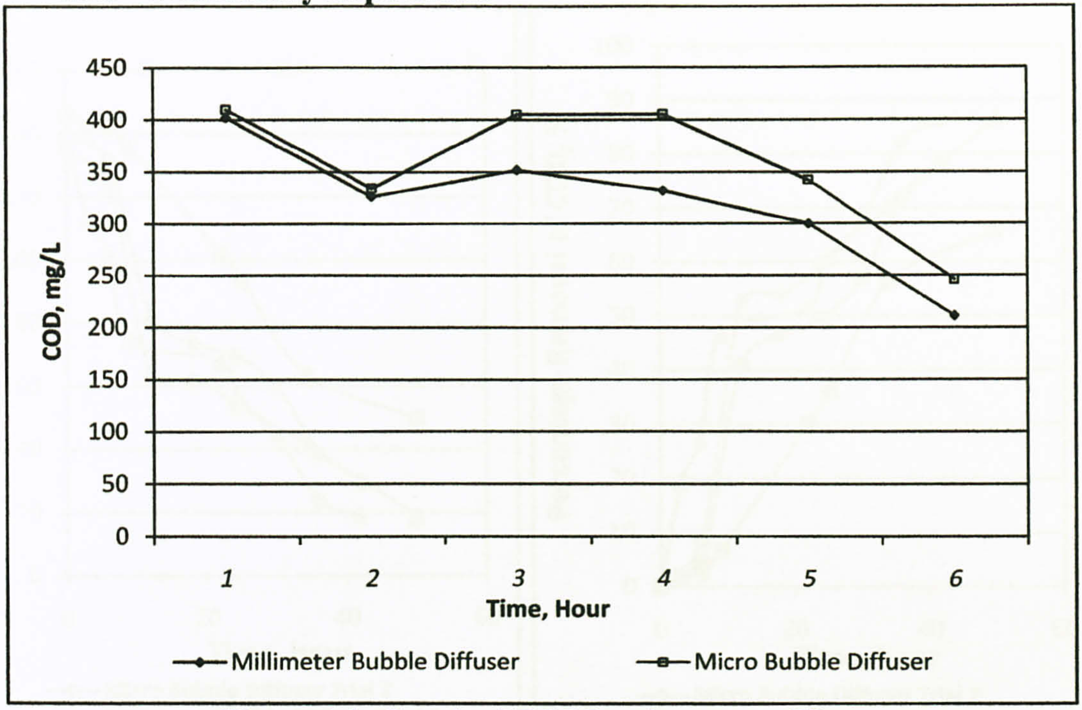


Figure 4.2: Graph of TCOD value versus Time

It was observed in this preliminary run that there was inadequate mixing in the reactor utilizing the millimeter bubble diffuser. Biomass was found to be settling at the bottom of the reactor. Hence, higher air flow rate would be required for millimeter bubble reactor to produce a lifting effect compared to micro bubble. However, it can be observed from Figure 4.2 that TCOD sampled decreased over the sampling period. Insufficient settling time prior to measurement of TCOD may also be a factor.

4.2.2 Main Experiment

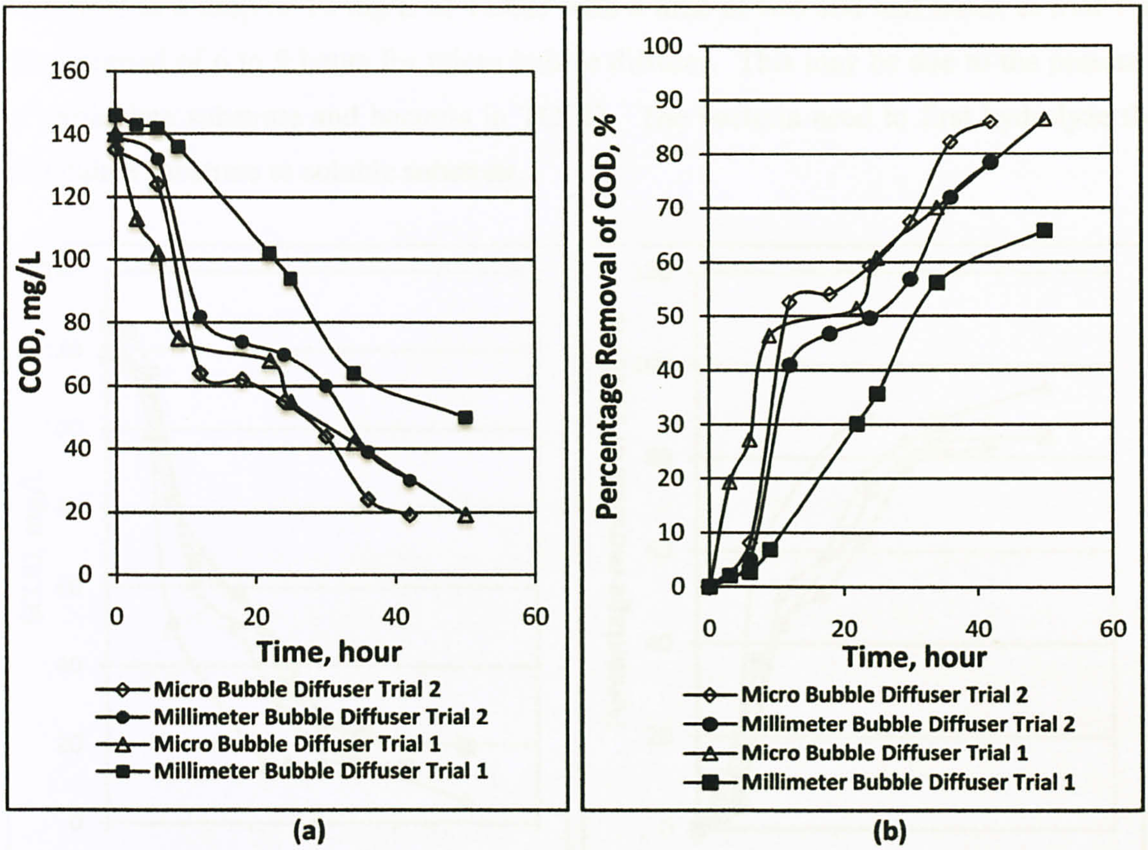


Figure 4.3: Graph of TCOD versus Time

From Figure 4.3(a) it can be observed that generally, the TCOD degraded throughout the sampling period. The TCOD removal shown in Figure 4.3 (b) rate of the organic matter for the micro bubble diffuser reactor was found to be greater than TCOD removal rate of the organic matter for the millimeter bubble diffuser reactor. Statistical analysis using T-tests conducted using Trial 1 on TCOD sampled for both reactors showed that at 5 % level of significance there was significant difference between TCOD sampled from both reactors. The average removal of TCOD was found to be 86.8 % and 80.4 % for the micro bubble and millimeter bubble diffusers, respectively. From the SCOD graph in Figure 4.4, it can be observed that removal rate of SCOD is greater for the micro bubble diffuser reactor. Statistical analysis using T-tests conducted using both trial on SCOD sampled for both reactors showed that at 5 % level of significance there was no significant difference between SCOD sampled from both reactors. More rapid SCOD removal was observed for a drop of 10 mg/L of SCOD at a time of half hours as compared to a drop of 10 mg/L of TCOD with a time of two and half hours in trial 1 at time interval of 6 to 9 hours for micro bubble diffuser. This may be due to the presence of particulate substrate and bacteria in TCOD. The bacteria need to first hydrolyze the particulate substrate to soluble substrate.

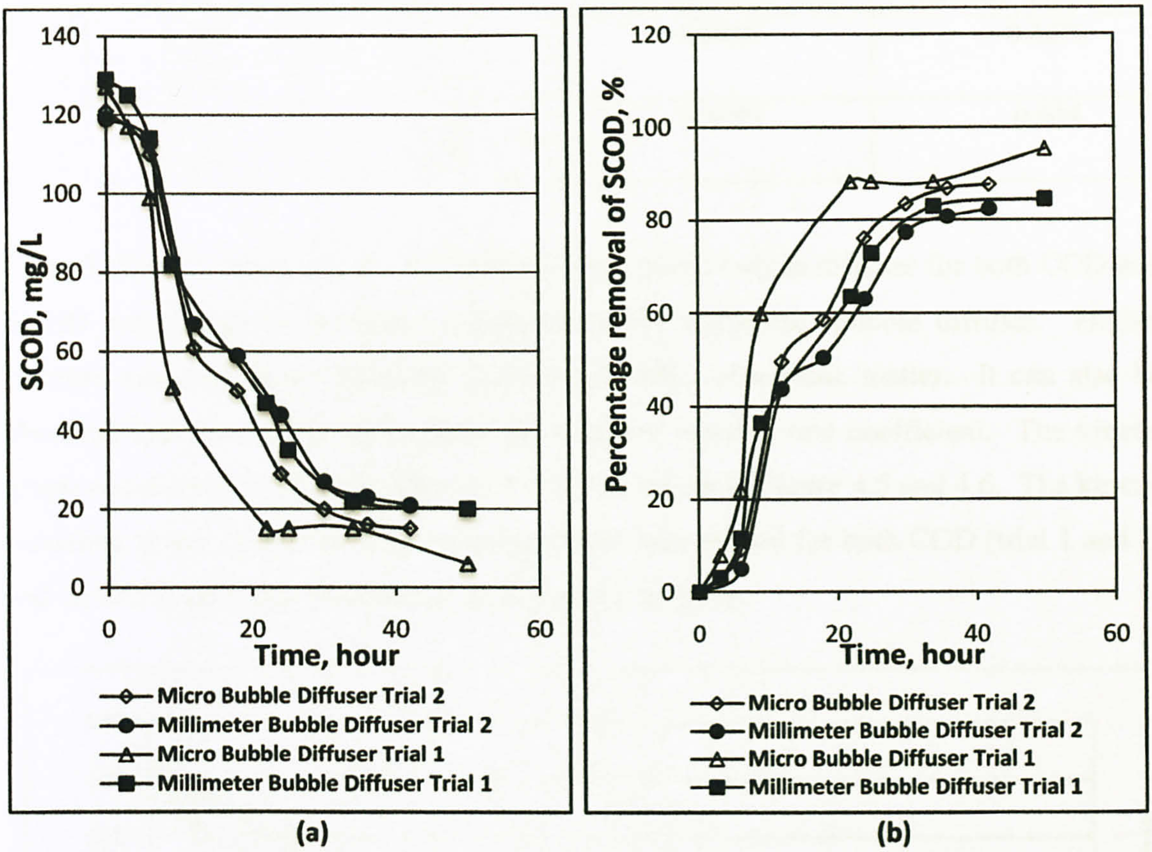


Figure 4.4: Graph of SCOD versus Time

4.2.3 Kinetics Modeling

Reaction rate coefficients, *k* for TCOD and SCOD removal are summarized in Table 4.1.

Table 4.1: Reaction rate coefficient

Trial		Kinetic Coefficient Rate (x/mg.hour)			
		Micro Bubble Diffuser	Millimeter Bubble Diffuser	Average	
				Micro Bubble Diffuser	Millimeter Bubble Diffuser
COD	1	0.046	0.032	0.0410	0.0275
	2	0.036	0.023		
SCOD	1	0.064	0.043	0.0595	0.044
	2	0.055	0.045		

From Table 4.1, reaction rate coefficient for the micro bubble diffuser for both COD and SCOD was found to be higher compared to the millimeter bubble diffuser. Higher reaction rate coefficient indicates faster degradation of organic matter. It can also be observed that removal of particulates gave higher reaction rate coefficient. The kinetic graph was plotted for both TCOD and SCOD as shown in Figure 4.5 and 4.6. The kinetic modeling graph against the experimental values was plotted for both COD (trial 1 and 2) and SCOD (trial 1 and 2) as shown in Figure 4.7 and 4.8.

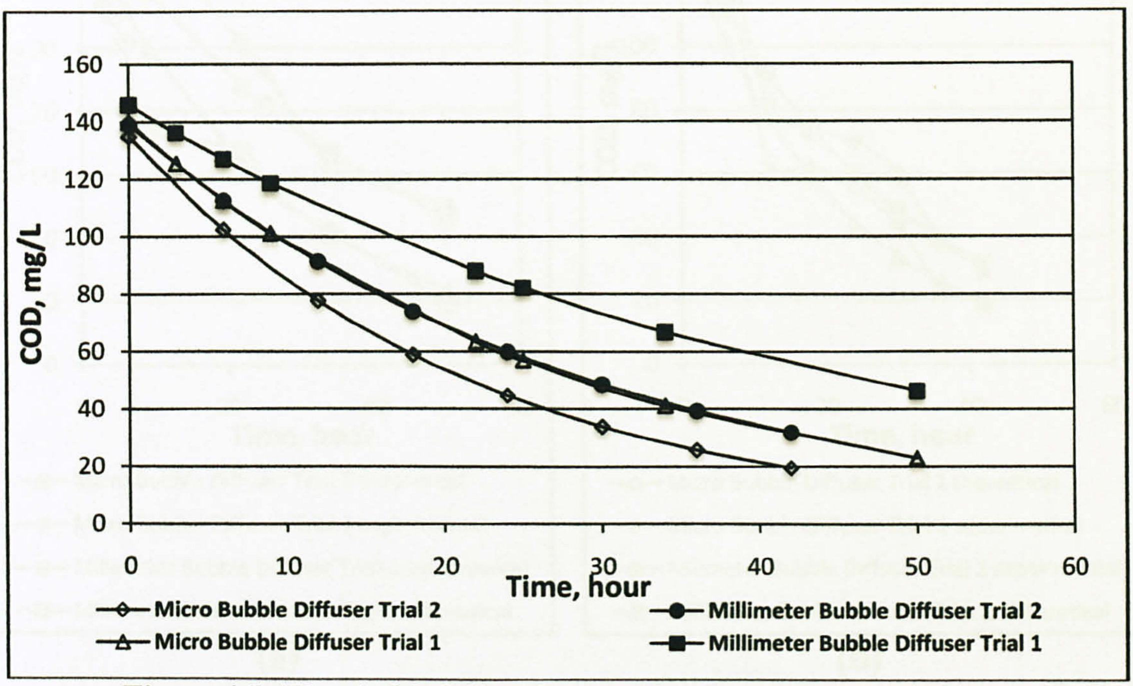


Figure 4.5: Kinetic Modeling Graph of TCOD value versus Time

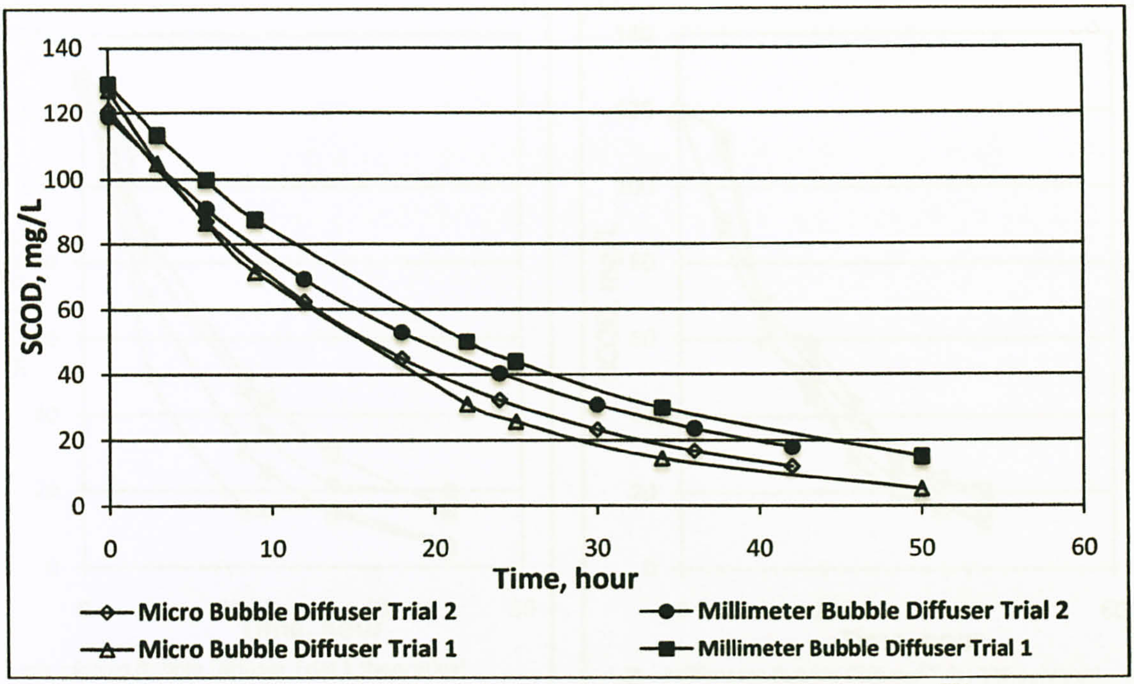
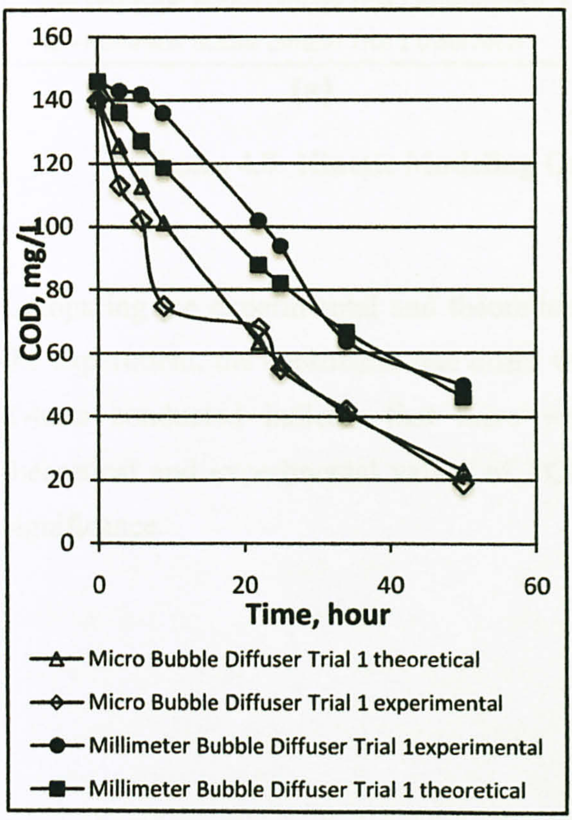
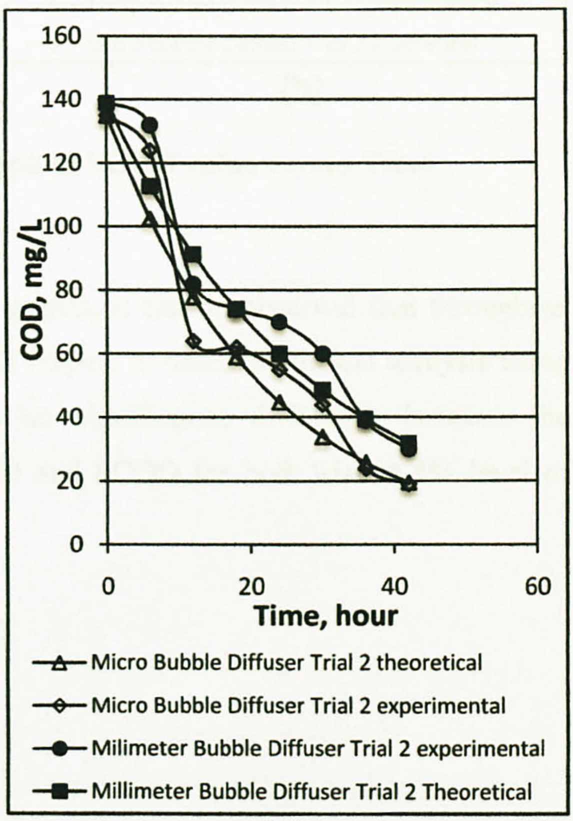


Figure 4.6: Kinetic Modeling Graph of SCOD value versus Time



(a)



(b)

Figure 4.7: Kinetic Modeling Graph of TCOD value versus Time

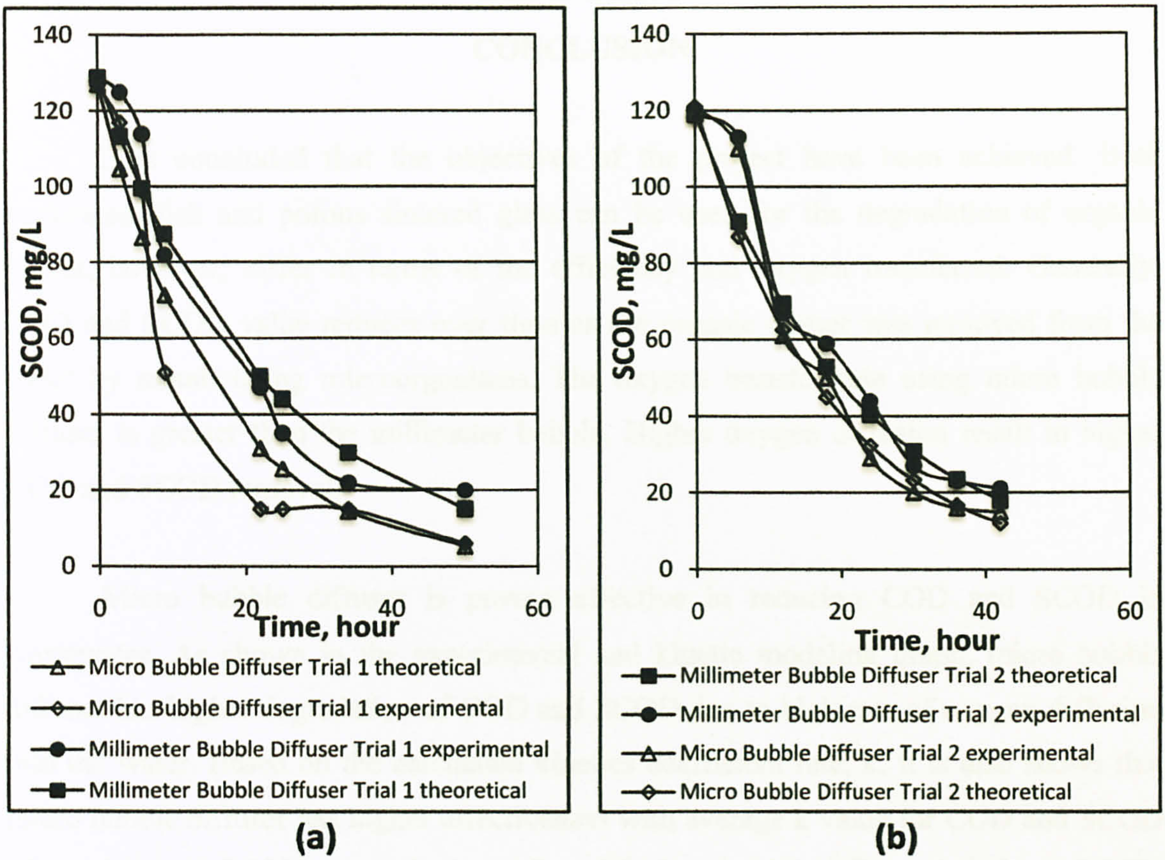


Figure 4.8: Kinetic Modeling Graph of SCOD value versus Time

Comparing the experimental and theoretical graphs, it can be observed that throughout the experiment, the coefficient rate differ with respect to time. Statistical analysis using T-tests conducted indicate that there was no significance difference between the theoretical and experimental values of TCOD and SCOD for both trial at 5% level of significance.

CHAPTER 5

CONCLUSION

It is concluded that the objectives of the project have been achieved. Both perforated disk and porous sintered glass can be used for the degradation of organic matter, however, differ in terms of the efficiency and oxygen transferred. Generally, COD and SCOD value reduces over time as the organic matter was removed from the water by metabolizing microorganisms. The oxygen transfer rate using micro bubble diffuser is greater than the millimeter bubble. Higher oxygen diffusion result in higher COD and SCOD removal.

Micro bubble diffuser is proven effective in reducing COD and SCOD in wastewater. As shown in the experimental and kinetic modeling graph, micro bubble diffuser has higher degradation of COD and SCOD due to high rate of oxygen diffusion into the water. Based on the calculated kinetics coefficient rate, k, it is also shows that micro bubble diffuser has higher effectiveness with average k value for COD and SCOD with 0.041 and 0.0595 respectively while millimeter bubble diffuser only have 0.0275 and 0.044 for COD and SCOD. Other than that, the effectiveness of micro bubble diffuser can be seen from the overall percentage removal of the system. On average micro bubble diffuser can remove 86.8 percent of COD and 90.86 percent of SCOD while millimeter bubble diffuser only can remove 80.39 of COD and 75.13 of SCOD. As its efficiency has been proven, micro bubble diffuser can be used as another alternative type of more efficient Sewage Treatment Plant aerators.

The experimental work also shows that micro bubble diffuser has greater degradation rate since it produces smaller size of air bubbles and it has wider surface interface between water in comparison with millimeter bubble diffuser. Moreover, turbulence effects in the reactor can be reduced because the smaller bubbles will provide laminar condition. The mixing process between the biomass and the substance is properly occurred. The air diffusion is efficient and oxygen transfer rate in the sample of wastewater is much greater. Therefore, it can enhance the organic matter degradation rate in wastewater treatment.

Millimeter bubbles have higher kinetic energy transfer for stirring process than that of the micro bubbles. The turbulence effect that occurs due to stirring process tends to prevent suspended particles on the water from lifted up. Bubble- water transfer contributes significantly to the total oxygen transfer in this type of diffused aeration system.

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APPENDIX

APPENDIX A

Table 1: Dissolved Oxygen (DO) over Time for Micro Bubble Diffuser

Pressure = 33 kPa			
Air Flow = 0.5 liter/minute			
Porosity 4 = 10 - 16 micron (Microbubble Diffuser)			
Temperature, T = 21.9°C			
Time (minutes)	DO (mg/L)	Time (minutes)	DO (mg/L)
0	9.44	56	9.67
2	9.52	58	9.67
4	9.56	60	9.67
6	9.61	62	9.67
8	9.63	64	9.67
10	9.63	66	9.67
12	9.65	68	9.67
14	9.65	70	9.67
16	9.65	72	9.67
18	9.66	74	9.67
20	9.66	76	9.67
22	9.67	78	9.67
24	9.67	80	9.67
26	9.67	82	9.67
28	9.67	84	9.67
30	9.67	86	9.67
32	9.67	88	9.67
34	9.67	90	9.67
36	9.67	92	9.67
38	9.67	94	9.67
40	9.67	96	9.67
42	9.67	98	9.67
44	9.67	100	9.67
46	9.67	102	9.67
48	9.67	104	9.67
50	9.67	106	9.67
52	9.67	108	9.67
54	9.67	-	-

APPENDIX B

Table 2: Dissolved Oxygen (DO) over Time for Millimeter Bubble Diffuser

Pressure = 34 kPa			
Air Flow = 0.5 liter/minute			
Millimeter diffuser (±1 mm)			
Temperature, T = 21.2˚C			
Time (minutes)	**DO (mg/L)**	**Time (minutes)**	**DO (mg/L)**
0	9.45	56	9.61
2	9.45	58	9.61
4	9.46	60	9.62
6	9.47	62	9.62
8	9.49	64	9.62
10	9.5	66	9.62
12	9.51	68	9.63
14	9.51	70	9.63
16	9.52	72	9.64
18	9.52	74	9.64
20	9.52	76	9.64
22	9.55	78	9.64
24	9.55	80	9.65
26	9.56	82	9.65
28	9.56	84	9.66
30	9.56	86	9.66
32	9.57	88	9.66
34	9.57	90	9.66
36	9.57	92	9.67
38	9.57	94	9.67
40	9.58	96	9.67
42	9.58	98	9.67
44	9.59	100	9.67
46	9.59	102	9.67
48	9.59	104	9.67
50	9.59	106	9.67
52	9.6	108	9.67
54	9.6	-	-

APPENDIX C

Preliminary Experiment

Table 3: Chemical Oxygen Demand (COD) Reduction over Time

COD			
Micro Bubble Diffuser		Millimeter Bubble Diffuser	
T	mg/L	T	mg/L
0	402	0	410
1	326	1	334
2	352	2	405
4	332	4	405
5	300	5	342
6	211	6	246

APPENDIX D

Full Experiment and Theoretical
Trial 2

Table 4: Experimental and Theoretical Data Sheet for SCOD

Time, hours	SCOD Experimental		ln (C/Co)		SCOD theoretical	
					k = 0.055/hour	k = 0.045/hour
	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser
0	121	119	2.087740344	1.734601055	121	119
6	110	113	1.992430165	1.682865381	86.98977175	90.84215983
12	61	67	1.402823663	1.160170182	62.53901147	69.34704203
18	50	59	1.203972804	1.033015006	44.96077961	52.93810988
24	29	44	0.659245629	0.739667196	32.32337154	40.41186755
30	20	27	0.287682072	0.251314428	23.23803894	30.84959102
36	16	23	0.064538521	0.090971778	16.70637771	23.54994519
42	15	21	0	0	12.01061144	17.97754525

Table 5: Experimental and Theoretical Data Sheet for COD

Time, hours	COD experimental		ln (C/Co)		COD theoretical	
					k = 0.046/hour	k = 0.035/hour
	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser
0	135	139	1.960835799	1.533276551	135	139
6	124	132	1.875842586	1.481604541	102.4397457	112.6712102
12	64	82	1.214444104	1.005521866	77.73260363	91.32950795
18	62	74	1.182695406	0.902867712	58.98450477	74.03026034
24	55	70	1.062894206	0.84729786	44.75820494	60.00776276
30	44	60	0.839750655	0.693147181	33.96310466	48.64134713
36	24	39	0.233614851	0.262364264	25.77164299	39.42790968
42	19	30	0	0	19.55585595	31.95964244

APPENDIX E

Full Experiment and Theoretical
Trial 1

Table 6: Experimental and Theoretical Data Sheet for SCOD

Time, hours	SCOD experimental		ln (C/Co)		SCOD theoretical	
					k = 0.064/hour	k = 0.043/hour
	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser
0	127	129	3.052427617	1.864080131	127	129
3	117	125	2.970414466	1.832581464	104.8139723	113.3876416
6	99	114	2.803360381	1.740466175	86.50369125	99.66478494
9	51	82	2.140066163	1.410986974	71.39209054	87.60275125
22	15	47	0.916290732	0.854415328	31.06827141	50.08955004
25	15	35	0.916290732	0.559615788	25.64085779	44.02741043
34	15	22	0.916290732	0.09531018	14.41381449	29.89862236
50	6	20	0	0	5.176799905	15.02645635

Table 7: Experimental and Theoretical Data Sheet for COD

Time, hours	COD experimental		ln (C/Co)		COD theoretical	
					k = 0.036/hour	k = 0.023/hour
	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser	Micro Bubble Diffuser	Millimeter Bubble Diffuser
0	140	146	1.997203443	1.071583616	140	146
3	113	143	1.78294884	1.050821625	125.6678635	136.2656953
6	102	142	1.680533834	1.043804052	112.8029423	127.180409
9	75	136	1.373049134	1.00063188	101.2550339	118.7008689
22	68	102	1.275068726	0.712949808	63.41132179	88.02374624
25	55	94	1.062894206	0.631271777	56.91975236	82.15491085
34	42	64	0.793230639	0.246860078	41.16722469	66.79355686
50	19	50	0	0	23.14184435	46.22896833

APPENDIX F

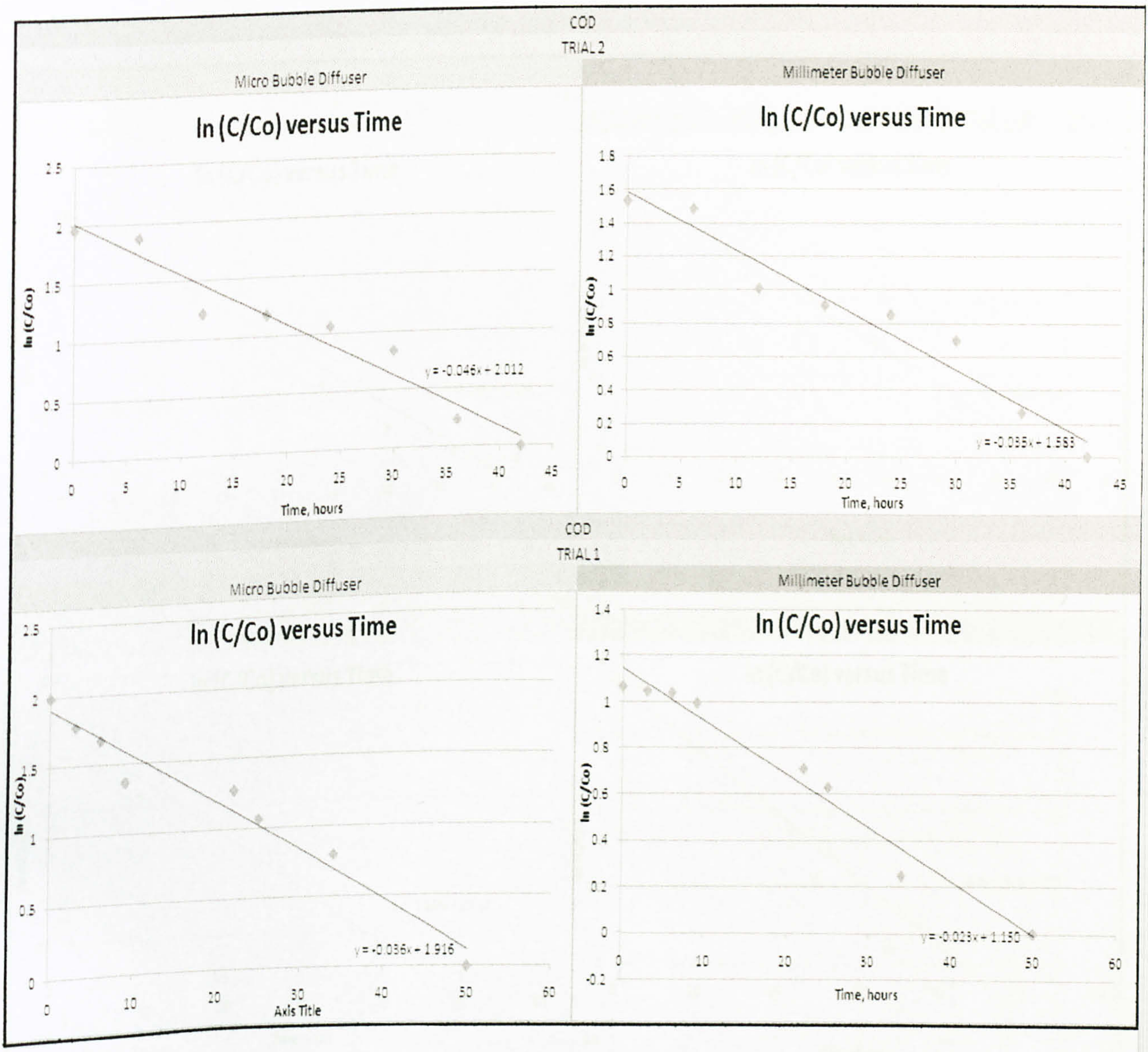

Figure 1: Graph of ln (C/C_0) COD value versus Time

APPENDIX G

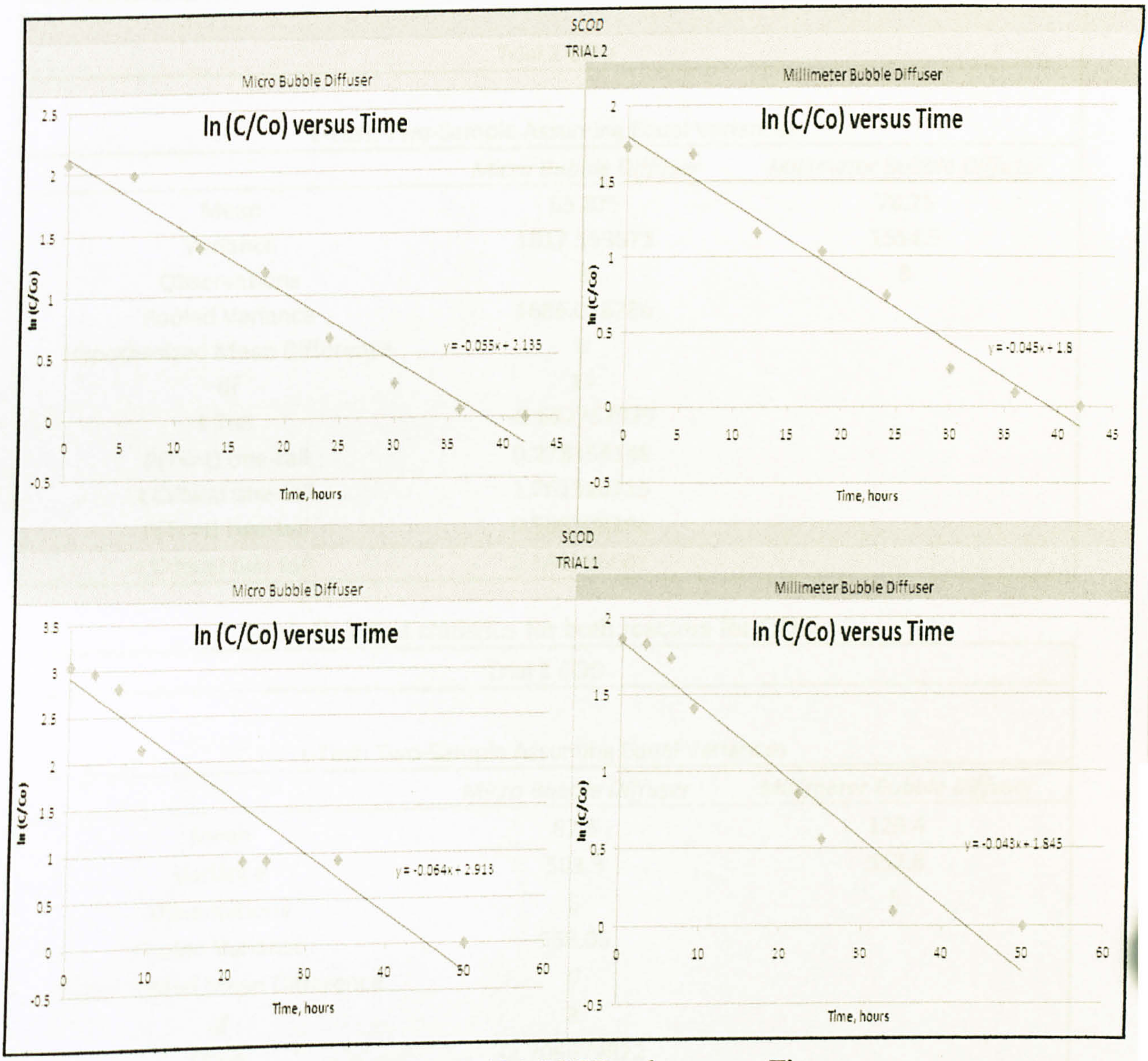

Figure 2: Graph of ln (C/C_0) SCOD value versus Time

APPENDIX H

Table 8: T-test statistics for both reactors for COD

Trial 2 COD		
t-Test: Two-Sample Assuming Equal Variances		
	Micro Bubble Diffuser	*Millimeter Bubble Diffuser*
Mean	65.875	78.25
Variance	1817.553571	1554.5
Observations	8	8
Pooled Variance	1686.026786	
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.602757979	
P(T<=t) one-tail	0.278154148	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.556308296	
t Critical two-tail	2.144786681	

Table 9: T-test statistics for both reactors for COD

Trial 1 COD		
t-Test: Two-Sample Assuming Equal Variances		
	Micro Bubble Diffuser	*Millimeter Bubble Diffuser*
Mean	82.6	123.4
Variance	583.3	552.8
Observations	5	5
Pooled Variance	568.05	
Hypothesized Mean Difference	0	
df	8	
t Stat	-2.706679822	
P(T<=t) one-tail	0.013397732	
t Critical one-tail	1.859548033	
P(T<=t) two-tail	0.026795464	
t Critical two-tail	2.306004133	

Table 10: T-test statistics for both reactors for SCOD

Trial 2 SCOD		
t-Test: Two-Sample Assuming Equal Variances		
	Micro Bubble Diffuser	*Millimeter Bubble Diffuser*
Mean	52.75	59.125
Variance	1774.785714	1509.839286
Observations	8	8
Pooled Variance	1642.3125	
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.314617072	
P(T<=t) one-tail	0.37884616	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.75769232	
t Critical two-tail	2.144786681	

Table 11: T-test statistics for both reactors for SCOD

Trial 1 SCOD		
t-Test: Two-Sample Assuming Equal Variances		
	Micro Bubble Diffuser	*Millimeter Bubble Diffuser*
Mean	55.625	71.75
Variance	2596.839286	2159.928571
Observations	8	8
Pooled Variance	2378.383929	
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.661285101	
P(T<=t) one-tail	0.259582514	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.519165028	
t Critical two-tail	2.144786681	

Table 12: T-test statistics for Micro Bubble Diffuser reactor for TCOD

Micro Bubble Diffuser

Trial 2 COD

t-Test: Two-Sample Assuming Equal Variances

	Micro Bubble Diffuser	Micro Bubble Diffuser
Mean	65.875	62.27570782
Variance	1817.553571	1631.102736
Observations	8	8
Pooled Variance	1724.328154	
Hypothesized Mean Difference	0	
df	14	
t Stat	0.173355306	
P(T<=t) one-tail	0.432426818	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.864853635	
t Critical two-tail	2.144786681	

Trial 1 COD

t-Test: Two-Sample Assuming Equal Variances

	Micro Bubble Diffuser	Micro Bubble Diffuser
Mean	76.75	83.04574786
Variance	1578.214286	1812.552426
Observations	8	8
Pooled Variance	1695.383356	
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.305804143	
P(T<=t) one-tail	0.382126872	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.764253744	
t Critical two-tail	2.144786681	

Trial 2 SCOD

	Micro Bubble Diffuser	Micro Bubble Diffuser
Mean	52.75	49.97099531
Variance	1774.785714	1453.168817
Observations	8	8
Pooled Variance	1613.977265	
Hypothesized Mean Difference	0	
df	14	
t Stat	0.138347262	
P(T<=t) one-tail	0.445968103	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.891936207	
t Critical two-tail	2.144786681	

Trial 1 SCOD

	Micro Bubble Diffuser	Micro Bubble Diffuser
Mean	55.625	58.25118721
Variance	2596.839286	2058.047124
Observations	8	8
Pooled Variance	2327.443205	
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.108871983	
P(T<=t) one-tail	0.457424548	
t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.914849096	
t Critical two-tail	2.144786681	

Table 13: T-test statistics for Millimeter Bubble Diffuser reactor for SCOD

Millimeter Bubble Diffuser					
Trial 2 COD			Trial 1 COD		
t-Test: Two-Sample Assuming Equal Variances			t-Test: Two-Sample Assuming Equal Variances		
	Millimeter Bubble Diffuser	*Millimeter Bubble Diffuser*		*Millimeter Bubble Diffuser*	*Millimeter Bubble Diffuser*
Mean	78.25	74.63345506	Mean	109.625	101.4185194
Variance	1554.5	1402.718601	Variance	1445.696429	1279.924254
Observations	8	8	Observations	8	8
Pooled Variance	1478.609301		Pooled Variance	1362.810341	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	14		df	14	
t Stat	0.188103616		t Stat	0.444599767	
P(T<=t) one-tail	0.426747331		P(T<=t) one-tail	0.331702458	
t Critical one-tail	1.761310115		t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.853494661		P(T<=t) two-tail	0.663404915	
t Critical two-tail	2.144786681		t Critical two-tail	2.144786681	
Trial 2 SCOD			Trial 1 SCOD		
	Millimeter Bubble Diffuser	*Millimeter Bubble Diffuser*		*Millimeter Bubble Diffuser*	*Millimeter Bubble Diffuser*
Mean	59.125	55.61453259	Mean	71.75	71.08715212
Variance	1509.839286	1249.078884	Variance	2159.928571	1749.300139
Observations	8	8	Observations	8	8
Pooled Variance	1379.459085		Pooled Variance	1954.614355	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	14		df	14	
t Stat	0.189034263		t Stat	0.02998564	
P(T<=t) one-tail	0.426389495		P(T<=t) one-tail	0.48825089	
t Critical one-tail	1.761310115		t Critical one-tail	1.761310115	
P(T<=t) two-tail	0.852778989		P(T<=t) two-tail	0.97650178	
t Critical two-tail	2.144786681		t Critical two-tail	2.144786681	